NATURAL DAYLIGHTING - AN ENERGY ANALYSIS

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ABSTRACT

To promote energy conscious design, a study was undertaken to analyze the implications of using daylighting in the design of a structure. An existing office building was selected for this study. Its specific construction features, materials, usage patterns and equipment were determined. From this data, its energy consumption was estimated using LOADCAL: a computer program based upon the ASHRAE methodology. Then, daylighting levels within the building were estimated.

Modifications to the structure were evaluated to determine if daylighting could be used more efficiently in the building. Two new glazing types were considered in this study. Evaluations were first made using a glass with a similar shading-coefficient but a higher visible-light-transmission than the existing glazing. This approach yielded excessively high illumination levels and was, therefore, unacceptable. In the second approach, a glazing with a similar visible-light-transmission factor but a lower shading coefficient was used. This yielded striking results.

By modifying the building with the new glazing and incorporating the available daylighting to reduce the existing artificial lighting level, a significant reduction in the estimated energy consumption was realized. The improved performance characteristics of the new glass, coupled with the reduced artificial lighting levels yielded a total energy reduction of approximately twenty-two percent.

PROCEDURE

The building's specific design features, construction methods and materials, daylighting availability, the building's mechanical and electrical equipment and energy management techniques were determined. Actual building usage data was developed through owner interviews and on-site investigations.

From these data, the building's energy consumption was estimated by LOADCAL: a computer analysis program based on the American Society of Heating Refrigerating and Air-conditioning Engineers' (ASHRAE's) load calculation manual procedure. A representative portion of the building, a typical open office level, was selected for analysis. The analysis accounted for specific building conditions, existing within the facility, as well as actual environmental factors.

Upon completing this analysis, the availability and usage of daylighting in the existing building was determined. This procedure involved estimating daylighting levels, at multiple locations within the typical office level.

Then, alternative building schemes were analyzed to determine if a more efficient design could be provided. This revised scheme did not, however, significantly alter the present architectural design of the facility.

A detailed description of the Twin Towers is presented. The discussion highlights the building's major construction features and materials. Electrical and mechanical systems are described along with energy saving and management techniques utilized in the design, construction and operation of the facility.

PROJECT DESCRIPTION

The Twin Towers office complex consists of four distinct interconnected facilities: the Georgia State Metropolitan Atlanta Rapid Transit Authority (MARTA) station, the entry plaza, the office towers, and a central energy plant. The project, located across Martin Luther King Drive from the State Capitol, is also bounded by Piedmont Avenue, Butler Street and by the Georgia Railroad trackage.

The impetus for the construction of these facilities was the CAPITOL HILL 2000 plan, a long-term master plan for development of facilities in the vicinity of the state capitol. A key recommendation of the master plan was the construction of two symmetrical state office buildings to house many of the state agencies. The buildings were to be located in air-rights over the proposed rapid-transit station. The office space would enable the state government to increase its efficiency by consolidating, into one location, many of the personnel who were located throughout the downtown area.

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THE BUILDING CONCEPT

As stated, the architect was charged with designing a facility with two identical towers. To improve the constructability of each tower, the number of floors was reduced from the concept outlined in the CAPITOL HILL 2000 plan. Furthermore, the area of each floor was increased to improve the space utilization within each tower. This measure eliminated the need for two tiers of elevators, which afforded both economic and energy savings. Because of the basic premise of the planning concept, the two-tower scheme, no consideration was given to combining the towers into a single larger-scaled tower.

ARCHITECTURAL CONSIDERATIONS

The building skin consists of masonry and glass. Prefabricated, medium color utility brick panels were selected as the predominant exterior cladding material. This selection was based upon a study of aesthetics, construction costs, life-cycle costs and thermal mass.

During the design, studies were made analyzing glazing and amounts of glass areas. These studies were based on aesthetics, natural versus artificial light, HVAC loads and views to the outside. The amount of glass utilized in the final design, as a percentage of the building enclosure within a typical 25 foot wide office bay, is approximately 39 percent. The glass on the north and south elevations is shaded by a brick spandrel which projects 18 inches. East-west facing glass is shaded by a 15 inch brick spandrel. Projecting brick columns help to shade the glass with north-south projections of 20 inches and east-west projections of 34 inches.

The glazing selected is a one-inch insulated, bronze tinted glass. The following table describes the design data on the glass used.

TABLE 1. GLASS DESIGN DATA

U-value (summer)	= .59
U-value (winter)	= .50
Shading Coefficient	= .46
Visible LightTransmission	= 32 %

Various window framing solutions were analyzed including operable windows, provided with and without integral blinds. Operable windows, which appeared a common sense solution, were shown not only to be cost prohibitive (approximately $500,000 in additional costs) but were counterproductive from an energy use standpoint.

By having a fixed window frame, the possible introduction of latent heat from humid summer air is reduced. In winter, the possible loss of heat through exfiltration is reduced by eliminating the large amount of window perimeter 'crack' found in operable windows. Exterior airborne dust intake is also reduced, which has adverse effects upon HVAC equipment.

Several types of insulation are used in the project. All construction U-values met those recommended by the codes in force at the time of the design and construction. The following table gives data on the major types found in the building.

TABLE 2. INSULATION DATA

Polyurethane and Perlite Roof Insulation	U-value = .06
Polystyrene Deck Insulation	U-value = .06
RigidFiberglass Masonry Panel Insulation	U-value = .11

Medium color, horizontal blinds are provided throughout the entire project. The one-inch blinds have a positive stop at 70 percent of the fully closed position. The blinds reduce the amount of direct solar radiation gain within the spaces. It is pointed out by the mechanical engineer that the blinds reduce the window shading coefficient by, a maximum of 28 percent to .33.

Shading Coefficient = .46
.46 x (.28) = .13
.46 - .13 = .33

Mechanical equipment penthouses are located on the rooftop of each tower. The mechanical engineer noted that with a lapse rate of 3 1/2 degrees (F) per 1000 feet, the location of the mechanical equipment on the roof affords the dominant cooling cycle a slight advantage over systems with a lower level intake.

MECHANICAL CONSIDERATIONS

Alternative fuel sources for the building were analyzed by the engineer. Coal, solid-waste, oil and natural gas were considered, as was off-peak generation. Using a commercially available load program, energy analyses were performed evaluating eight options of HVAC equipment and energy sources. These analyses included such items as chiller, condenser and fan equipment on variable volume systems. The building envelope was also analyzed using a computer program based on ASHRAE's Standard 90-75.

HVAC FEATURES INCORPORATED

A variable-air-volume ventilation

system is employed throughout the building. No 'reheat' is allowed within the system. Vane-axial supply and return air fans were selected which give the maximum fan power savings and the maximum turn-down ratio available. Heating is provided by low-temperature, hot-water, finned-piped convectors located under the perimeter windows of the building.

Rotary total heat exchangers are used to capture approximately 72 percent of the loss/gain of the central toilet exhaust system. An air-side economizer cycle, with enthalpy control, reduces mechanical cooling requirements below 78 degrees (F) outdoor temperature. It also provides free cooling below 55 degrees (F) outdoor temperature.

Space temperature and ventilation control is provided by induction boxes. These boxes reclaim up to 50 percent of the heat from the lights by inducing warm air from the ceiling plenum to the exterior areas where heat is needed in winter. In the summer, this heat is returned to the mechanical penthouse where it is removed by the refrigeration system.

Control Systems and Automation. A central control room has been incorporated into the Twin Towers and from this point all systems within the towers are monitored. Critical functions are controlled by building engineers from this room.

A number of energy conserving control measures are employed in the operation of the facility. Space temperature set-backs are employed during non-occupancy hours. Both the ventilation and the exhaust systems are automatically shut-off during the pre-occupancy warm-up period. Automatic air-temperature and hot-water resets are employed based upon outside air temperature.

LIGHTING CONSIDERATIONS

Because occupancy requirements were not known prior to construction, considerable flexibility had to be designed into the lighting system. Both open and traditional office layouts were anticipated in the tenant occupancy. Therefore, a variety of conditions had to be addressed in the design of the lighting system.

Given the constraints cited above, four sources of illumination were analyzed using a life-cycle cost comparison. They are mercury, fluorescent, metal-halide and high-pressure sodium. Fluorescent lighting was selected based upon this analysis.

While comparisons of color, appearance and rendering properties were made, cost was the final determinant in selecting a four-tube fluorescent troffer system for general office illumination. The fluorescent system provides the state's requirement of 70 footcandles, for office occupancy, with approximately 2.4 watts per square foot energy usage.

High Intensity Discharge source fixtures are provided in the lower levels of the plaza where greater ceiling heights exist. They are also used for general outdoor lighting. A minimum of incandescent lighting is used spaces such as electrical and janitorial closets.

The owner undertook an energy conservation program to reduce the light-wattage per square foot, in the lighting system. In the open plan portions of each tower, two of the four lamps were disconnected in many in reception, waiting and circulation areas. The ballast serving these delamped fixtures, however, were not disconnected. While the delamping of fixtures reduced the power consumption, greater reductions could be realized by disconnecting the unused ballast in each fixture. A final measure included individual switching of lights in individual offices. These steps were implemented under the direction of the project's design team.

LOADCAL ANALYSIS

In the preceding section, items such as the building's major construction and materials, electrical and mechanical systems and the energy management systems were described. These items were presented and discussed to highlight the systems and components used within the project. With this description provided, we can now focus upon the analyses to be performed on the project. These analyses will be the basis for recommending any modification to the structure.

An energy analysis was performed on a representative portion of the building: a typical open plan office level. LOADCAL, the estimation program used, is based on ASHRAE's Load Calculation Manual analysis procedure. It calculates the cooling and heating load of a space (or building.) The program takes into account environmental and interior factors which affect the mechanical requirements of the space. To ensure that the results of this analysis were as representative as possible, an intermediate office floor was selected. This eliminated any effects caused by having a roof transfer load.

The typical open office floor was divided into four perimeter zones and one interior zone. Each perimeter zone has one exterior exposure. The orientation of the northern zone (zone four) is 40.82 degrees east of true-north. Floor, wall and glazing areas were taken directly from the architectural plans. Wall configurations, overhang and vertical fin dimensions were also derived from the plans. Data concerning U-values were established based on the information contained in the drawings and specifications. They were verified with the project's mechanical engineer.

Typical Atlanta weather data was used in this analysis. The data was taken from meteorological tables, with 1984 being the base year. The solar radiation intensity, however, was set to equal 1.0 for all evaluations. This value represents a clear sky condition. Actual levels vary, of course, with the degree of cloud cover, smog and/or other atmospheric conditions which block available solar radiation, thus, reducing the intensity. The effect of using the 1.0 value is a somewhat over-estimated solar radiation load than found under normal sky conditions. The increased loading condition used for this analysis will be used in the revised building analysis, thus, allowing for comparable results. Actual intensity data for Atlanta is being developed by others, at this writing.

Analysis data for interior areas represents actual building use conditions. This information was obtained through on-site inspections and from verification with the owners of the project, the Georgia Building Authority. Thermostats maintain a relatively constant year-round temperature of 74 degrees (F).

Humidity ratios used in this analysis are 0.0060 pound-vapor for the winter months and 0.0103 pound-vapor in the summer months. These values represent typical Atlanta design data.

Light wattage data was calculated from the architectural and electrical drawings. They were verified through on-site visits and in discussions with the owner. Lighting levels, in footcandles, were checked using a hand-held illumination meter. The readings indicated that a minimum level of 70 footcandles existed throughout the office areas. Some areas had higher illumination levels.

The light-wattage value established for each zone represents lighting and equipment loads for that zone. Equipment loads were factored, by the ballast factor of the lighting equipment, to eliminate the possibility of over-estimating the total zone wattage value. Light fixture and lamp data was taken directly from the architectural drawings and specifications.

The ballast factor was obtained directly from the supplier of the fixtures and the lamps. The delamping plan, as implemented by the owner, was accounted for in the determination of the lighting wattage data. The lighting usage represents actual conditions, as the lights are left on continually from morning occupancy until the cleaning crews have finished late at night.

The building is typically occupied Monday through Friday, from 8:00 am until approximately 5:00 pm. The occupant loading is based upon the owner's design criteria of one person per 150 square feet of floor area. This closely represents actual conditions as state government buildings are occupied less densely than typical speculative office buildings. Zones one through four reflect this occupant load condition while zone five is a service zone and the occupant loading here, which is much less, was estimated.

The ventilation rate is ten (10) cubic feet per minute (per person) within the building. The mechanical system employs a rotary total heat exchanger, which is 72 percent efficient; thus, the impact of the ventilation rate on the mechanical system is reduced as shown in the following equation.

Ventilation Rate = 10cfm/person
Heat Exchanger = 72 percent efficient
(1.0 - .72 = .28)
Fresh Air Induction which must
be Conditioned by HVAC System =
10 * .28 = 2.8 cfm/person.

The system only operates while the building is occupied and therefore a "non-continuous" factor was entered into the LOADCAL program.

LOADCAL estimates the annual cooling and heating load to be approximately 1.31 * 10 (9) BTUs, per year, for the existing office floor analyzed. This translates into approximately 64,088 BTU/SF/YEAR for the typical, 20,400 square foot, office level.

An appendix which contains the actual LOADCAL computer analysis of the facility will be available for review at the symposium. The input data, found on the initial pages, contains general project data, outside weather data and inside target data. Specific zone-by-zone data, for all bays, derived to analyze the building is also included.

Results from the LOADCAL analysis follow the input data and have been provided in a zone-by-zone format. A floor summary, which sums the results of the zones one through five, is also provided.

This concludes the LOADCAL energy analysis of the existing building. The following section estimates the available daylighting levels.

MAXIMUM HOURLY VALUES

MON	MAX HR COOL	MAX HR HEAT
JAN	112,845	-19,038
FEB	114,438	-15,449
MAR	107,624	-10,868
APR	105,940	-4,739
MAY	123,642	0
JUN	133,735	0
JUL	138,024	0
AUG	122,146	0
SEP	120,032	0
OCT	124,459	-4,036
NOV	118,523	-12,907
DEC	112,524	-18,725
ANN	138,024	-19,038

TOTALS (BTU'S)

	COOL LOAD	HEAT LOAD	TOTAL LOAD
JAN	80,336,345	-10,140,689	90,477,034
FEB	78,392,888	-6,739,516	85,132,404
MAR	94,761,916	-4,340,496	99,102,412
APR	101,792,160	-737,040	102,529,200
MAY	117,195,531	0	117,195,531
JUN	124,452,780	0	124,452,780
JUL	142,220,374	0	142,220,374
AUG	133,539,599	0	133,539,599
SEP	120,979,860	0	120,979,860
OCT	108,031,683	-872,619	108,904,302
NOV	87,417,210	-5,034,060	92,451,270
DEC	80,701,494	-9,707,991	90,409,485
ANN	1,269,821,840	-37,572,411	1,307,394,251

ITEM SUMMARY

MON	LIGHTING	PEOP LAT	PEOP SEN	VENT LAT	VENT SEN	ROOF	GLASS CON	GLASS SHG	WALL
JAN	71,741,471	7,502,000	7,492,452	966,580	3,037,659	0	43,328,080	37,106,628	6,314,576
FEB	64,798,748	6,776,000	6,767,376	781,200	2,379,132	0	35,384,384	36,490,552	4,634,588
MAR	71,741,471	7,502,000	7,492,452	356,500	1,964,749	0	32,039,492	41,635,666	3,589,428
APR	69,427,230	7,260,000	7,250,760	1,427,400	763,590	0	18,449,760	38,875,290	1,232,550
MAY	71,741,471	7,502,000	7,492,452	151,900	444,664	0	9,397,216	37,992,949	1,004,369
JUN	69,427,230	7,260,000	7,250,760	1,917,900	788,910	0	6,372,720	35,669,520	2,397,600
JUL	71,741,471	7,502,000	7,492,452	4,218,480	1,561,036	0	8,920,560	36,843,066	4,157,565
AUG	71,741,471	7,502,000	7,492,452	2,693,280	1,007,159	0	6,487,680	38,047,633	2,838,980
SEP	69,427,230	7,260,000	7,250,760	1,131,000	521,310	0	7,251,840	38,380,470	1,651,710
OCT	71,741,471	7,502,000	7,492,452	1,219,230	655,774	0	17,377,360	38,277,219	1,701,652
NOV	69,427,230	7,260,000	7,250,760	295,800	1,834,980	0	30,629,280	35,195,190	3,989,970
DEC	71,741,471	7,502,000	7,492,452	915,740	2,900,422	0	41,899,600	36,121,138	6,147,796
ANN	844,697,965	88,330,000	88,217,580	16,075,010	17,859,385	0	257,537,972	450,635,321	39,660,784

TABLE 3. EXISTING BUILDING
LOADCAL FLOOR SUMMARY

DAYLIGHTING ANALYSIS

Analyzing the existing daylighting levels, within the typical office level, involved defining such factors as the typical level's geographical orientations and specific zone configurations. In the LOADCAL analysis, the typical office floor was divided into five zones, with each perimeter zone having one orientation. For this analysis, the perimeter zones are further subdivided into bays. This is done in order to effectively determine the available daylighting.

Each bay was analyzed to determine dimensions, ceiling heights and surface reflectance (ceiling, wall and floor) values. Specific window conditions including orientation, area, transmittance value and blind usage, were established. Direct sunlight could not enter the space due to the positive stop provided with the horizontal blinds. Typical adjustment angle was observed to be approximately 45 degrees.

Actual Atlanta meteorological data, was used in this analysis. Solar altitude angles and azimuths were calculated for specific times and then window-to-sun orientations were established.

Illumination levels, at the windows of each bay, were determined for various times of the day, under clear and cloudy sky conditions. Coefficients of utilization were established based upon the specific bay and window conditions. From these factors, daylighting levels were calculated on three work surfaces, located within each bay. Daylighting levels were calculated for the following times: 8:00 a.m., 10:00, 12 noon, 2:00 and 4:00 p.m., for March 21st, June 21st and December 21st. (Note: illumination levels for September 21st equals the levels for March 21st).

A computer spreadsheet was developed to calculate the daylighting levels described above. The spreadsheets, used to determine the daylighting levels, will be available for review at the symposium.

Following, in Figure One, are two sample graphs which describe the daylighting levels for bay number one (eastern orientation) at March 21st, for the times and sky conditions noted on each graph.

The daylighting levels, which vary depending upon bay orientation, time of day and sky condition, are the basis for evaluating any modification to the existing building. The strategy is to utilize the available daylighting to reduce artificial lighting levels, thereby, improving the thermal performance of the structure, which reduces the operating costs.

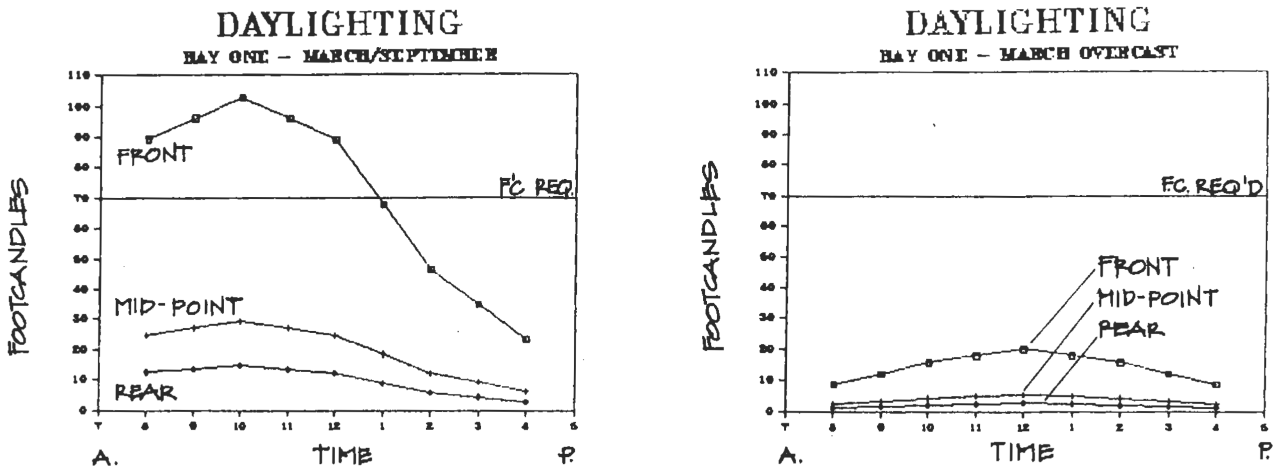

FIGURE 1. DAYLIGHTING AVAILABILITY GRAPHS

REVISED BUILDING SCHEME DESCRIPTION

As stated earlier, the goal of this investigation is to analyze the implications of using daylighting on a building's thermal load. In an effort to effectively analyze this issue, without having to consider the possible interactive effects of multiple alterations, the basic building design was not significantly altered. Changes to the overall design, such as modifications to floor height, window configuration, overhang or vertical fin depths were not considered. The addition of reflectors or sun screens were not considered. Building usage patterns nor operational procedures could not be altered. With these constraints established, as the basis for defining alternative solutions, the only remaining element for consideration is the window glazing.

The existing glazing is a bronze-tinted, double insulating glass. It has a shading coefficient of .46, a visible light transmittance of 32 percent and a U-value (winter) of .50. It was a good glass selection, considering the types available, when the facility was constructed.

Now, however, glazings with greatly improved performance characteristics are available. Low-emissivity glass and specialty coated glazings are available. The price range of these new glazings is comparable to existing insulating glass.

In selecting a new glazing for this building, the following factors were evaluated for the types available: the shading coefficient, the visible light transmittance and the U-value of the glazing.

The new glass should have the lowest shading coefficient factor available and the highest visible light transmittance. This provides the lowest amount of solar heat-gain in relation to the amount of daylighting entering the space. By having a low shading coefficient and high light-transmittance, daylighting is provided while the heat associated with the light is filtered out.

The U-value needs to be as low as possible to cut down on the conductive heat losses/gains to/from the environment. Eliminating these adverse effects will make the space 'feel' more comfortable for cold drafts in the winter and radiated heat in summer will be reduced.

The methodology for selecting a new glazing, at the out-set, was to select one with a shading coefficient comparable to the existing and a visible light transmittance factor as high as possible. While this approach was sound from the standpoint that existing artificial lighting levels could be greatly reduced, the amount of natural daylighting provided was

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excessive and, thus, unacceptable. The lighting levels generated were so great that glare and over-illumination would have made the space impossible to work in, especially at window locations.

The opposite approach was then investigated. By selecting a glazing with a transmittance comparable to the existing with the lowest available shading coefficient, the results were more acceptable. While the availability of natural daylighting did not change significantly (it was actually decreased by six percent from the levels available in the existing design), the solar gain associated with the daylight was decreased dramatically.

The glazing selected is a solar reflective, double-insulating glazing with a gold-tinted low-emissivity coating applied to the number three surface. The visible light transmittance is 30 percent, lower than the existing by six percent. The shading coefficient factor is .19, which is 59 percent lower than the existing. The U-value (winter) is also much lower at .23 compared to .50 for the existing.

This one modification has the potential of providing considerable energy savings, if only by improving the thermal performance of the glazing. However, when accounting for the artificial lighting level reductions possible by incorporating the available daylighting, an even greater thermal load reduction is probable.

REVISED DAYLIGHTING ANALYSIS

Daylighting data was developed for the revised building scheme. This procedure involved factoring the existing building daylighting values by the six percent reduction of the transmittance factor.

Once these values were determined, an average illuminance availability was calculated for each bay. This was done for the times, months and sky conditions calculated in the earlier daylighting analysis. Yearly illumination levels were then established for each bay. These yearly values were factored by a 'usage factor' based on daylighting availability in relation to lighting requirements, in terms of hours per day. Then, these yearly averages were compared against the lighting level requirement of 70 footcandles. The Appendix will have a complete listing of all calculation methods and derived data.

From these calculations, reductions in the existing artificial lighting level, expressed as percentages, were determined. A 15 percent reduction in the artificial lighting level is possible within bays one and two. In bays three and four, a nine percent reduction is possible.

It must be noted that while incorporating the available daylighting allows for reduced artificial lighting levels, they cannot be permanently reduced. A control device, or devices, is required to increment the amount of artificial lighting reduction, based upon the contribution of daylighting at any given time. This is due to the ever changing nature of daylighting.

REVISED LOADCAL ANALYSIS

Data concerning the modified building: the new U-value, the new shading coefficient and the reduced artificial lighting levels, were entered into the LOADCAL program for analysis. All other building usage and design factors remained as described in the original analysis.

The results are described in the following section. The revised LOADCAL analysis data will be available for review. It is presented in the same format as provided for the original building analysis.

RESULTS

By modifying the existing building with the new glazing and incorporating the available daylighting to reduce the artificial lighting level, significant reductions in the estimated energy consumption is realized.

The much improved U-value (winter) 53.99 percent in the glazing conductive heat transfer. While being significant in terms of the amount of actual heat loss/gain, it will also have the effect of increasing the comfort level of the space. This is accomplished by cutting down on cold down-drafts near the windows in the winter and the conductive heat gain in the summer.

The lower shading coefficient provides a 58.95 percent reduction in the solar heat gain to the space. This is a considerable reduction, especially when one realizes that the amount of natural daylighting entering the building was reduced only six percent. (The visible light transmittance is 30 percent for the new glass, while the existing glass was 32 percent.)

The reduced thermal load afforded by lower artificial lighting levels, is 10.51 percent. While this may not seem significant, when compared to the reductions above, it is a tremendous amount of energy considering the overall lighting level of 70 footcandles is still provided at each work surface. And when one realizes the amount of electrical consumption saved, by the artificial lighting reduction, the actual energy savings are significant.

Another significant reduction that this modification affords is a 33.57 percent reduction in the peak-hourly-cooling load of the space. While this will save considerably in the overall energy consumption, it will yield great economic savings on the amount of peak-electrical demand charges applied to the electrical consumption. It could also provide considerable construction cost savings since all mechanical equipment must be sized to handle the maximum hourly cooling load. Should the owner decide to install the new glazing as a retrofit program and reduce the artificial lighting levels within the building, additional savings could be realized by rebalancing the mechanical system. The greatest potential savings would, however, result in applying this analysis to the design of a totally new facility.

Finally, the total thermal load reduction afforded by these modifications is 22.25 percent. This is quiet a significant reduction when one considers the simple modifications that were suggested.

DISCUSSION OF THE RESULTS

The amount of thermal load reductions and economic savings provided are significant by any standard. This is especially true considering that the suggested modifications, to the existing building, are very minor compared to methodologies typically employed to reduce energy consumption levels of a structure. As noted earlier, the cost of the new glazing is comparable with other insulating glazings, and when factored for inflation, not significantly more expensive than the existing glazing in the building.

The economic justification, for making this modification to the facility, has been proven with reduced thermal loading, lower electrical consumption for lighting and cooling, reduced peak-load electrical surcharges and through reduced mechanical plant size requirements.

REFERENCE

1. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.; Cooling and Heating Load Calculation Manual New York; ASHRAE; 1979.

TABLE 4. REVISED BUILDING LOADCAL FLOOR SUMMARY DATA

MAXIMUM HOURLY VALUES

MON	MAX HR COOL	MAX HR HEAT
JAN	61,931	-7,929
FEB	63,180	-5,719
MAR	61,823	-3,361
APR	71,363	-80
MAY	80,811	0
JUN	87,352	0
JUL	91,775	0
AUG	83,854	0
SEP	74,001	0
OCT	70,930	0
NOV	66,033	-4,578
DEC	61,964	-7,753
ANN	91,775	-7,929

TOTALS (BTU'S)

	COOL LOAD	HEAT LOAD	TOTAL LOAD
JAN	67,134,003	-2,787,923	69,921,926
FEB	64,161,188	-1,583,624	65,744,812
MAR	76,496,995	-698,647	77,195,642
APR	80,936,670	-2,400	80,939,070
MAY	92,085,097	0	92,085,097
JUN	96,374,370	0	96,374,370
JUL	108,405,822	0	108,405,822
AUG	102,503,298	0	102,503,298
SEP	93,611,730	0	93,611,730
OCT	86,604,824	0	86,604,824
NOV	71,981,040	-942,900	72,923,940
DEC	67,564,717	-2,625,297	70,190,014
ANN	1,007,859,754	-8,640,791	1,016,500,545

ITEM SUMMARY

MON	LIGHTING	PEOP LAT	PEOP SEN	VENT LAT	VENT SEN	ROOF	GLASS CON	GLASS SHG	WALL
JAN	64,203,697	7,502,000	7,641,190	966,580	3,037,659	0	19,931,264	15,249,272	6,314,576
FEB	57,990,436	6,776,000	6,901,720	781,200	2,379,132	0	16,278,192	14,982,520	4,634,588
MAR	64,203,697	7,502,000	7,641,190	356,500	1,964,749	0	14,739,570	17,101,708	3,589,428
APR	62,132,610	7,260,000	7,394,700	1,427,400	763,590	0	8,488,020	15,943,380	1,232,550
MAY	64,203,697	7,502,000	7,641,190	151,900	444,664	0	4,323,384	15,583,111	1,004,369
JUN	62,132,610	7,260,000	7,394,700	1,917,900	788,910	0	2,931,480	14,612,070	2,397,600
JUL	64,203,697	7,502,000	7,641,190	4,218,480	1,561,036	0	4,102,974	15,118,576	4,157,565
AUG	64,203,697	7,502,000	7,641,190	2,693,280	1,007,159	0	2,984,246	15,598,146	2,838,980
SEP	62,132,610	7,260,000	7,394,700	1,131,000	521,310	0	3,336,240	15,795,900	1,651,710
OCT	64,203,697	7,502,000	7,641,190	1,219,230	655,774	0	7,994,156	15,728,811	1,701,652
NOV	62,132,610	7,260,000	7,394,700	295,800	1,834,980	0	14,089,860	14,461,440	3,989,970
DEC	64,203,697	7,502,000	7,641,190	915,740	2,900,422	0	19,274,560	14,831,051	6,147,796
ANN	755,946,755	88,330,000	89,968,850	16,075,010	17,859,385	0	118,473,946	185,005,985	39,660,784